WHAT IS CLAIMED IS:

1. A process comprising:

pretreating a hydrocarbon feedstock comprising impurities to provide a purified feedstock and a residual feedstock, wherein

the purified feedstock comprises a lower concentration of impurities than the hydrocarbon feedstock before pretreatment,

the residual feedstock comprises a higher concentration of impurities than the purified feedstock; and

contacting the residual feedstock with an effective amount of sodium metal and an effective amount of exogenous capping agent at a temperature of 250-500°C, to produce a mixture of sodium salts and a converted feedstock, wherein

the residual feedstock comprises hydrocarbons with a sulfur content of at least 0.5 wt% and an asphaltene content of from 2 wt% to 40 wt%;

the sulfur content comprises asphaltenic sulfur and non-asphaltenic sulfur;

the converted feedstock comprises hydrocarbon oil with a sulfur content less than that in the residual feedstock and an asphaltene content less than that in the residual feedstock;

the proportion by weight of asphaltenic sulfur to non-asphaltenic sulfur in the converted feedstock is lower than in the residual feedstock; and

wherein the exogenous capping agent is hydrogen, hydrogen sulfide, natural gas, methane, ethane, propane, butane, pentane, ethene, propene, butene, pentene, dienes, isomers of the forgoing or a mixture of any two or more thereof.

2. A process comprising:

contacting a hydrocarbon feedstock with an effective amount of sodium metal and an effective amount of exogenous capping agent at a temperature of 250-500°C, to produce a mixture of sodium salts and a converted feedstock, wherein

the hydrocarbon feedstock comprises hydrocarbons with a sulfur content of at least 0.5 wt% and an asphaltene content of from 2 wt% to 40 wt%;

the sulfur content comprises asphaltenic sulfur and non-asphaltenic sulfur;

the converted feedstock comprises hydrocarbon oil with a sulfur content less than that in the hydrocarbon feedstock and an asphaltene content less than that in the hydrocarbon feedstock;

the proportion of asphaltenic sulfur to non-asphaltenic sulfur in the converted feedstock is lower than in the hydrocarbon feedstock;

wherein the exogenous capping agent is hydrogen, hydrogen sulfide, natural gas, methane, ethane, propane, butane, pentane, ethene, propene, butene, pentene, dienes, isomers of the forgoing or a mixture of any two or more thereof.

3. A process comprising:

pretreating a hydrocarbon feedstock to provide a purified feedstock and a residual feedstock, wherein

the purified feedstock comprises a lower concentration of impurities than the hydrocarbon feedstock before pretreatment, and

the residual feedstock comprises a higher concentration of impurities than the purified feedstock; and

contacting a residual feedstock, the residual feedstock comprising hydrocarbons with a sulfur content of at least 0.5 wt% and an asphaltene content of from 2 wt% to 40 wt%, with

a less than stoichiometric amount of sodium metal to the sulfur content of the residual feedstock, and

an effective amount of exogenous capping agent at a temperature of 250-500°C, to produce a mixture of sodium salts and a converted feedstock, wherein

the stoichiometric amount of sodium metal to sulfur content is the theoretical amount of sodium metal required to convert all sulfur content in the residual feedstock to sodium sulfide;

the converted feedstock comprises a hydrocarbon oil with a sulfur content less than that in the residual feedstock and an asphaltene content less than that in the residual feedstock;

wherein the exogenous capping agent is hydrogen, hydrogen sulfide, natural gas, methane, ethane, propane, butane, pentane, ethene, propene, butene, pentene, dienes, isomers of the forgoing or a mixture of any two or more thereof.

4. A process comprising:

pretreating a hydrocarbon feedstock comprising impurities to provide a purified feedstock and a residual feedstock, wherein

the purified feedstock comprises a lower concentration of impurities than the hydrocarbon feedstock before pretreatment, and

the residual feedstock comprises a higher concentration of impurities than in the purified feedstock;

contacting the residual feedstock with an effective amount of sodium metal and an effective amount of exogenous capping agent at a temperature of 250-500°C, to produce a mixture of sodium salts and a converted feedstock, wherein

the residual feedstock comprises hydrocarbons with a sulfur content of at least 0.5 wt% and an asphaltene content of from 2 wt% to 40 wt%;

the converted feedstock comprises a converted hydrocarbon oil with a sulfur content less than that in the residual feedstock and an asphaltene content less than that in the residual feedstock;

at least a portion of the converted hydrocarbon oil derives from asphaltenes in the residual feedstock; and

wherein the exogenous capping agent is hydrogen, hydrogen sulfide, natural gas, methane, ethane, propane, butane, pentane, ethene, propene, butene, pentene, dienes, isomers of the forgoing or a mixture of any two or more thereof.

5. The process of any one of claims 1, 3 and 4, wherein the pretreatment step comprises (a) phase separation by an externally applied field, separation by addition of heat, hydroconversion, thermal conversion, catalytic conversion, catalytic treatment, solvent extraction, solvent deasphalting or a combination of any two or more thereof; and/or (b) contacting the hydrocarbon feedstock with exogenous hydrogen and/or a catalyst to remove one or more of sulfur, nitrogen, oxygen, metals and asphaltenes.

6. The process of any one of claims 1, 3, and 4, wherein the hydrocarbon feedstock is or is derived from a virgin crude oil or a product of a thermal cracking process.

7. The process of any one of claims 1-6, wherein the hydrocarbon feedstock is selected from the group consisting of petroleum, heavy oil, bitumen, conventional crude oil, shale oil, and oil shale.

8. The process of any one of claims 1-7, wherein the sulfur content ranges from 0.5 wt% to 15 wt%.

9. The process of any one of claims 1 or 3-8, wherein the residual feedstock comprises one or more of refinery intermediate streams, hydrocracker residue, hydroprocessing residue, FCC slurry, residual FCC slurry, atmospheric or vacuum residuums, solvent deasphalting tar, deasphalted oil, visbreaker tar, high sulfur fuel oil, low sulfur fuel oil, asphaltenes, asphalt, steam cracked tar, LC-Fining® residue, or H-Oil® residue.

10. The process of any one of claims 1 - 9, wherein the hydrocarbon feedstock or the residual feedstock has a viscosity from 1 to 10,000,000 cSt at 50°C and a density of 800 to 1200 kg/m^3 at 15.6°C.

11. The process of any one of claims 1 or 3-10, wherein the residual feedstock is a solid at room temperature.

12. The process of any one of claims 1 or 3-11, wherein the residual feedstock has a higher concentration of impurities than the hydrocarbon feedstock.

13. The process of claim 3, wherein the sulfur content comprises asphaltenic sulfur and non-asphaltenic sulfur, and the proportion of asphaltenic sulfur to non-asphaltenic sulfur in the converted feedstock is lower than in the residual feedstock.

14. The process of any one of claims 1-13, wherein the viscosity of the converted feedstock is reduced by at least 50 cSt at 50°C or at least by 40%, and the density of the converted feedstock is reduced by about 5 to about 25 kg/m^3 per wt% of the reduction in sulfur content of the converted feedstock compared to the hydrocarbon feedstock or residual feedstock.

15. The process of any one of claims 1-14, wherein the iron and vanadium content of the converted feedstock have been reduced by at least 40% compared to the hydrocarbon feedstock or residual feedstock.

16. The process of any one of claims 1-15, wherein the nickel content of the converted feedstock has been reduced by at least 40% compared to the hydrocarbon feedstock or residual feedstock.

17. The process of any one of claims 4-16, wherein at least 40% of the asphaltene content in the residual feedstock is converted to a liquid hydrocarbon oil in the converted feedstock.

18. The process of any one of claims 1 and 3-17, wherein the residual feedstock is combined with sodium metal at a pressure of 500 psig to 3000 psig.

19. The process of any one of claims 1 and 3-17, wherein the reaction of residual feedstock with sodium metal occurs for a time from 1 minute to 120 minutes.

20. The process of any any one of claims 1-19, further comprising separating the sodium salts from the converted feedstock,

wherein the separating comprises

a. heating the mixture of sodium salts and converted feedstock with elemental sulfur to a temperature from about 150°C to 500°C to provide a sulfur-treated mixture comprising agglomerated sodium salts; and

b. separating the agglomerated sodium salts from the sulfur treated mixture, to provide a desulfurized liquid hydrocarbon and separated sodium salts.

21. The process of claim 20, further comprising electrolyzing the separated sodium salts to provide sodium metal;

wherein the electrolyzing is carried out in an electrochemical cell comprising an anolyte compartment, a catholyte compartment, a NaSICON membrane that separates the anolyte compartment from the catholyte compartment, wherein a cathode comprising sodium metal is disposed in a catholyte in the catholyte compartment, an anode comprising the sodium salts are disposed in anolyte in the anolyte compartment, and an electrical power supply is electrically connected to the anode and cathode.

22. The process of any one of claims 1-21, wherein the sodium salts comprise one or more of sodium sulfide, sodium hydrosulfide, or sodium polysulfide.

23. The process of any one of claims 1, 3, and 5-22, wherein at least a portion of the hydrocarbon oil derives from asphaltenes in the residual feedstock.